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# Prediction of Annual Maximum Daily Rainfall Based on Probability Analysis

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**Abstract**

Probability analysis was carried out to evaluate the most suitable probability distribution for prediction of annual maximum daily rainfall at Azamgarh (Uttar Pradesh). The daily rainfall data of 20 years (1982—2001) obtained from meteorological observatory, Azamgarh were used for the analysis. In this study, an attempt was made to find out the goodness of fit of the observed annual maximum daily rainfall with the predicted values of rainfall computed by using theoretical probability distributions namely, Log Pearson Type III, Log Normal and Gumbel distributions. The best theoretical probability distribution was adjudged by comparing the sum of Chi-square values for each distribution corresponding to all return periods. Based on the smallest value of Chi-square as compared to other two distributions ; log normal distribution was found to be best probability model for predicting annual maximum daily rainfall of Azamgarh.

**Key words : Annual maximum daily rainfall, Chi-square test, Probability analysis.**

Frequency analysis of rainfall is an important tool for solving various water management problems. The determination of annual maximum rainfall is of great importance in many hydrologic designs. Design engineers and hydrologists need one-day maximum rainfall at different frequencies or return periods for appropriate planning and design of small and medium hydraulic structures such as small dams, culverts, bridges (1). It is also considered as an important parameter for flood forecasting. Due to variation in temporal rainfall distribution, it is necessary to determine the probability of occurrence of rainfall using various probability distributions. Based on theoretical probability distributions, it could be possible to make probability statement of rainfall of various magnitudes with different return periods. Several distributions have been suggested for hydrological analysis earlier (2—4). Probability distributions, most commonly used to estimate the rainfall frequency are Log Normal distribution, Log Pearson Type III distribution and Gumbel distribution. The frequency analysis of one-day maximum rainfall has been attempted for different purposes at various places by several researchers (5—9). In this study, an attempt was made to find the best probability model for predicting annual maximum daily rainfall for different return periods of Azamgarh in Uttar Pradesh.

## Methods

The daily rainfall data for 20 years (1982—2001) were obtained from meteorological observatory, Azamgarh, located at 26° N latitude and 83° E longitude, 77.6 m above mean sea level. From the data, values of one-day maximum rainfall were computed for the purpose of analysis. The return periods for various annual daily rainfall values were computed using Weibull's formula as given below :

$$T = \frac{N + 1}{m} \quad \ldots (1)$$

where, T is the return period in years, N is the total number of years of record and m is the rank of the observed rainfall value when arranged in descending order. The probability of exceedence of rainfall is the reciprocal of T values.

Chow (10) has suggested that rainfall analysis by theoretical probability distributions can be done by using frequency factor, K based on some statistical parameters from the observed data.

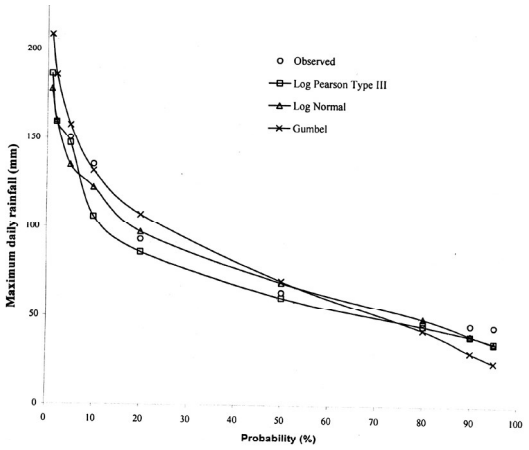


Fig. 1. Annual maximum daily rainfall at different probability levels

**Figure 1.** Annual maximum daily rainfall at different probability levels.

*Log Pearson Type III Distribution*

According to this distribution, the value of variate X (rainfall) is transformed to logarithm (base 10). The expected rainfall value R can be obtained by the following relationship :

$$R = \text{antilog } X \text{ and}$$
$$\text{Log } X = M + KS$$

where, M is the mean of the logarithmic values of observed rainfall and S is the standard deviation of these values. The frequency factor, K was taken from Benson (11) corresponding to the coefficient of skewness of the transformed variate.

*Log Normal Distribution*

In this distribution, the value of rainfall (X) is replaced by its natural logarithm. The expected value of rainfall R can be obtained by using the formula :

$$R = \text{Exp } (X) \text{ and}$$

$$\text{Ln } X = \bar{M} \ (1 + Cv.K) \qquad ...3$$

where, $\bar{M}$ is the mean of natural logarithm values of X and $C_v$ is the coefficient of variation of natural logarithmic values of X. The frequency factor, K corresponding to the skewness coefficient is taken from Chow (10).

*Gumbel Distribution*

According to this distribution, the expected rainfall R is computed by the formula :

$$R = \bar{X} + K S \qquad ...(4)$$

where, $\bar{X}$ is the mean of observed rainfall values and S is the standard deviation of observed rainfall values. The frequency factor, K corresponding to return period, T is taken from Chow (10).

## Results and Discussion

The recorded rainfall data for 20 years of

**Table 1.** Chi-square test of goodness of fit for theoretical probability distributions.

| | | | Expected rainfall (E), mm | | | $\chi^2 = (O-E)^2 / E$ | | |
|---|---|---|---|---|---|---|---|---|
| Probability (%) | Return period T (Years) | Observed rainfall (O), (mm) | Log Pearson Type III | Log Normal | Gumbel | Log Pearson Type III | Log Normal | Gumbel |
| 95 | 1.05 | 44.74 | 35.97 | 35.56 | 24.95 | 2.14 | 2.37 | 16.74 |
| 90 | 1.11 | 45.52 | 39.66 | 40.07 | 30.56 | 0.86 | 0.74 | 7.32 |
| 80 | 1.25 | 47.07 | 45.11 | 49.11 | 42.89 | 0.08 | 0.08 | 0.40 |
| 50 | 2.00 | 63.64 | 60.62 | 69.14 | 69.90 | 0.09 | 0.43 | 0.55 |
| 20 | 5.00 | 93.06 | 85.90 | 97.19 | 106.96 | 0.59 | 0.17 | 1.80 |
| 10 | 10.0 | 135.19 | 105.92 | 122.25 | 131.53 | 8.09 | 1.37 | 0.10 |
| 5 | 20.00 | 150.33 | 147.05 | 134.78 | 157.40 | 0.07 | 0.07 | 0.31 |
| 2 | 50.00 | – | 159.22 | 160.10 | 185.61 | – | – | – |
| 1 | 100.00 | – | 186.20 | 177.71 | 208.48 | – | – | – |
| | | | | | Total | 11.92 | 5.23 | 27.22 |

Azamgarh gives the average annual rainfall of 879.14 mm, with the minimum of 565.9 mm and the maximum of 1313.27 mm. About 90% of rainfall is received during monsoon months i.e. from June to September. The annual maximum daily rainfall varied from 35.5 mm in the year 1987 to 150.9 mm in 1990.

The return periods for different rainfall values were computed using Equation (1). Based on various statistical parameters, the expected values of rainfall corresponding to different return periods were calculated using Equations (2) to (4) for Log Pearson Type III, log normal and Gumbel distributions. The graphical representation of observed and predicted rainfall at different probability levels is shown in Figure 1. It is evident that predicted rainfall values for log normal distribution are the closest to the observed values of rainfall.

### *Chi-square Test of Goodness of Fit*

This test is widely applicable to various problems of hydro-meteorological nature. It is primarily used for testing the agreement of the observed data with those expected upon a given hypothesis. The Chi-square variate ($\chi^2$) can be calculated as :

$$\chi^2 = \sum_{i=1}^{n} (O_i - E_i)^2 / E_i \qquad \ldots (5)$$

where, $O_i$ and $E_i$ are the observed and predicted values of rainfall. The probability distribution with the least sum of Chi-square values will be adjudged the best (1).

The Chi-square values for each distribution were also calculated using Equation (5) and are presented in Table 1. The best theoretical probability distribution was adjudged by comparing the sum of Chi-square values for each distribution corresponding to different return periods. The sum of Chi-square values for Log Pearson type III, log normal and Gumbel distributions were found to be 11.92, 5.23 and 27.22, respectively. Since the log normal distribution has the smallest value of Chi-square as compared to other distributions. therefore, log normal distribution gives the best fit for the predicted annual maximum daily rainfall values at Azamgarh. According to this distribution, annual maximum daily rainfall for 50 years return period is expected to be 160.1 mm.

Thus, it can be concluded that log normal distribution was found to be the best probability model for predicting annual maximum daily rainfall of Azamgarh (Uttar Pradesh). Hence, appropriate planning of soil and water conservation measures, hydrological design of structures and drainage measures in and around Azamgarh can be based on maximum one-day rainfall predicted by log normal distribution.

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